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**DRAFT Preliminary Review:  
Navy Groundwater Flow Model  
for the Navy Red Hill Facility**

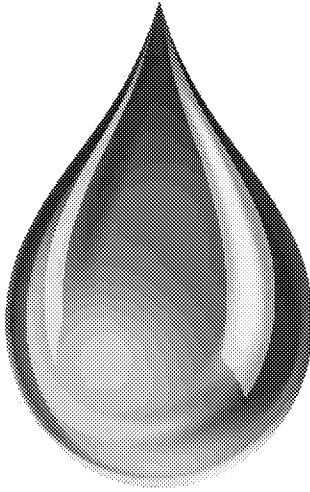
*By:*

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Technical subject matter experts  
Robert Whittier, Don Thomas, G.D. Beckett & Anay Shende*

*May XX, 2021*

## One Overarching Goal

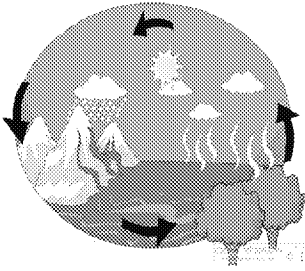
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- The purpose of this deliverable is to refine the existing groundwater flow model and improve the understanding of the direction and rate of groundwater flow within the aquifers around the Facility (AOC, 2015)
  - *To do this, the underlying geologic conditions must be refined and better understood in light of new data not available to prior modeling*

# The Navy Has Delivered Multiple Models

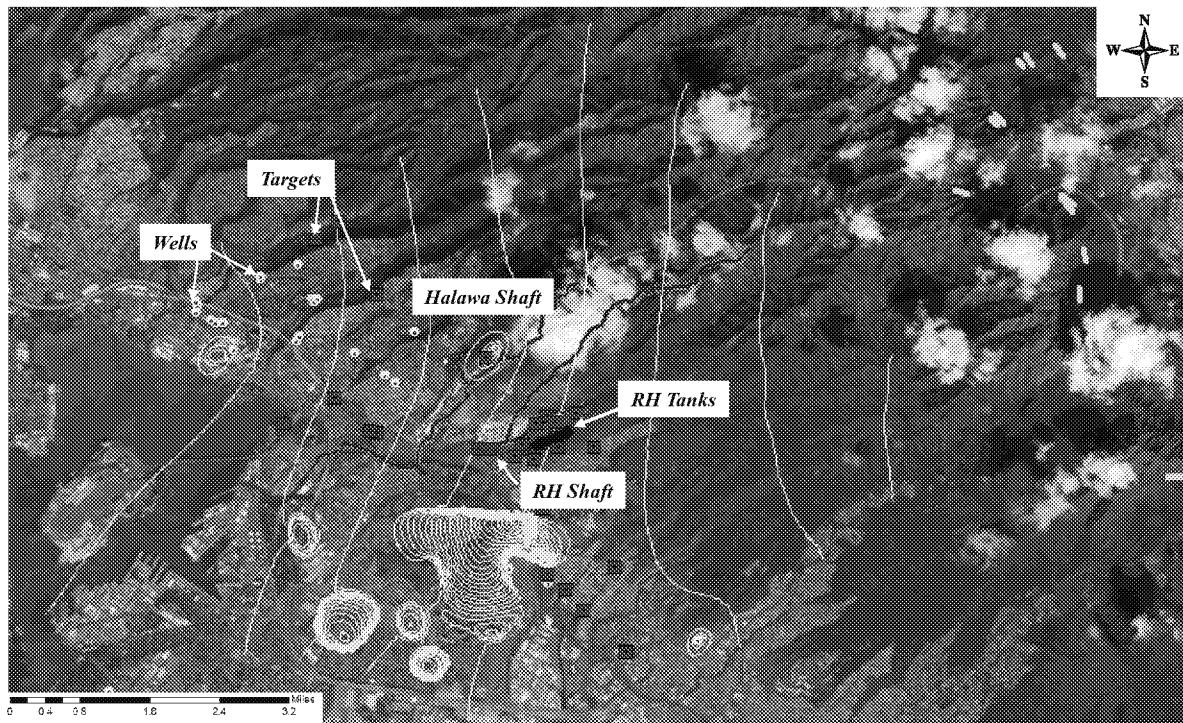
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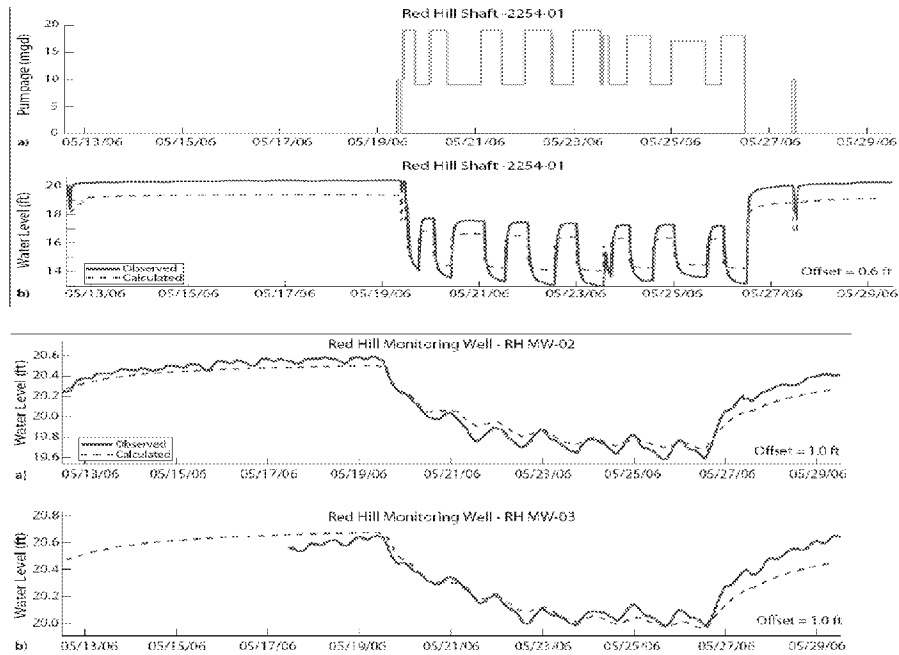
- Key review questions:
  - Do the models represent local heads?
  - Do the models represent gradients?
  - Do the models reflect transient aspects?
    - Pumping from Red Hill & Halawa shafts
    - Monitoring well “groupings”
  - Do transient simulations better past models?
  - Are models consistent with geochemistry?
  - Are models consistent with COCs?
  - Are models parameters justified?
- Will the model inform risk estimates?
  - Most uncertain aspect is NAPL
    - Where is it presently & in what state?
    - How far/fast could releases travel?
  - Is there any basis for down-scaling?

# General Area/Model Map

(Halawa Shaft On, RH Shaft Off)



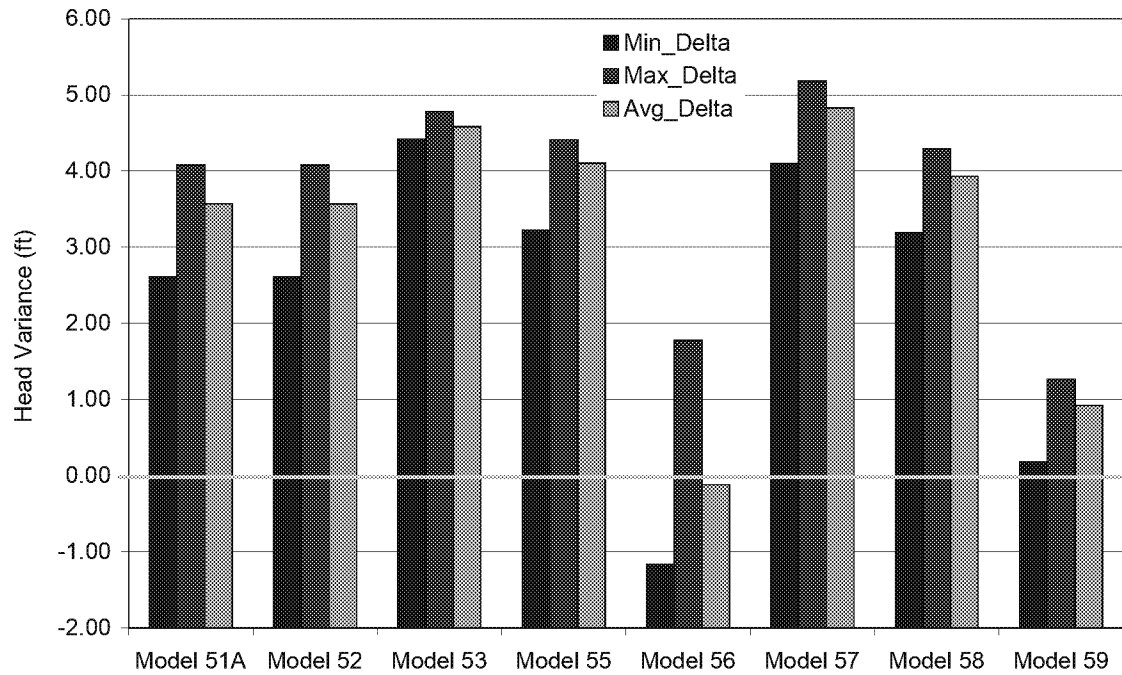
# The Primary Issue with Prior Model (calibrated to drawdown, but not to heads; complexity)



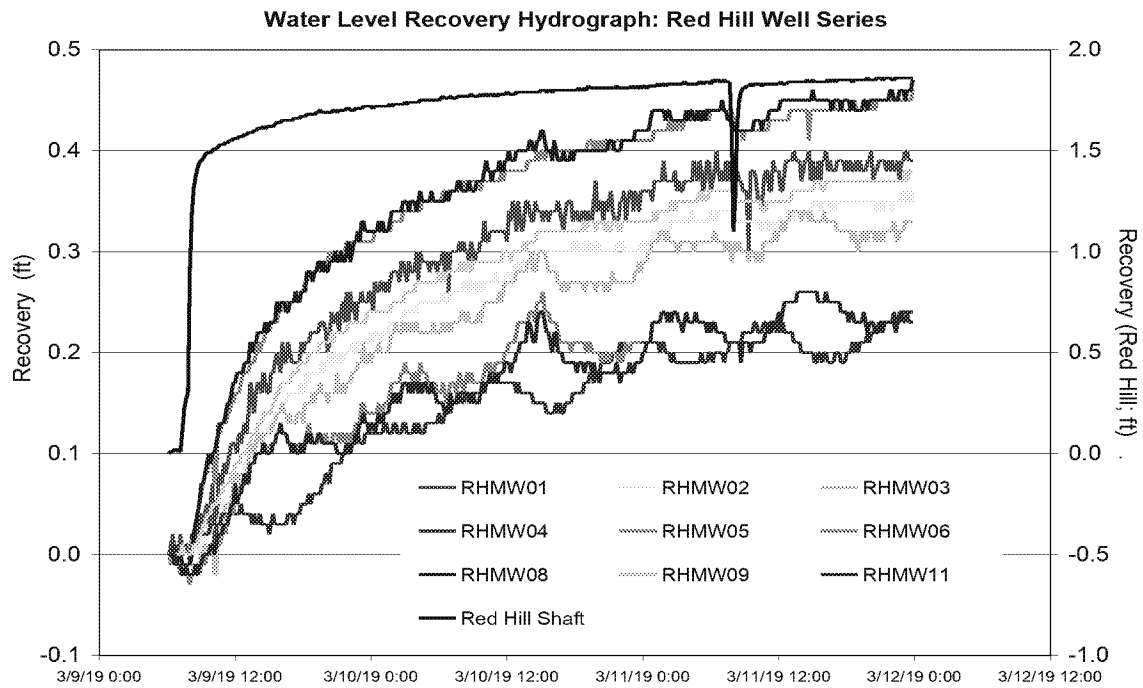
Kolja Rotzoll and Aly I. El-Kadi, 2007

# GW Elevation Variance – Transient Models

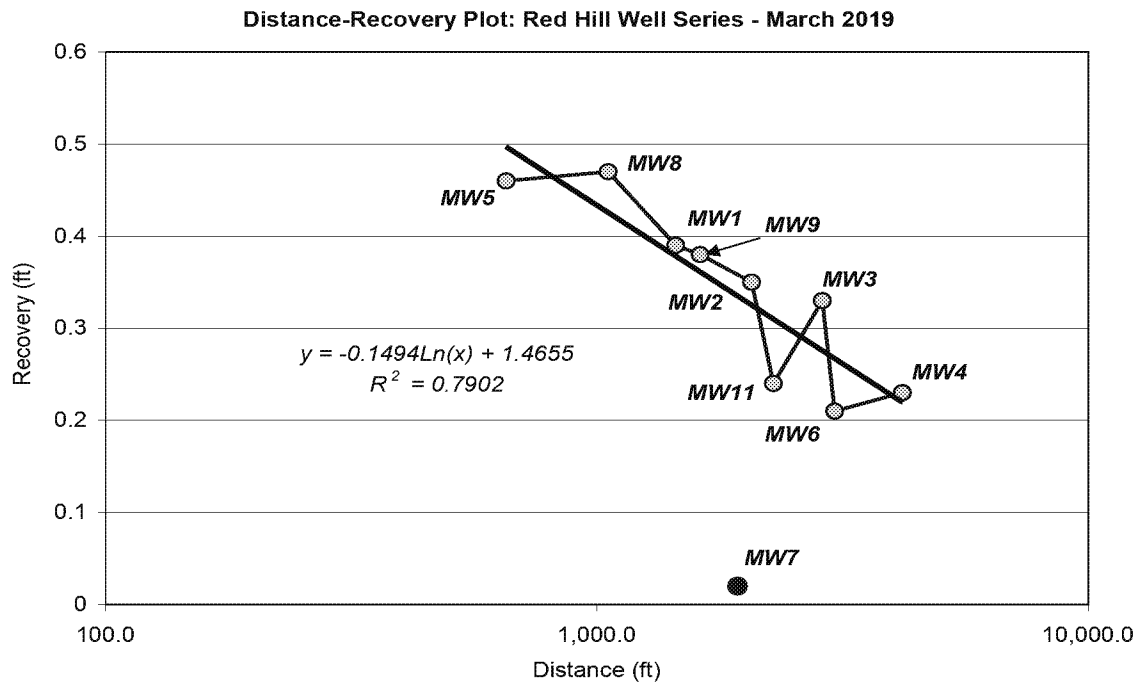
Modeled Groundwater Elevations Compared to Actual Synoptic Data  
Verification Model Variances to Measured Red Hill Area Well



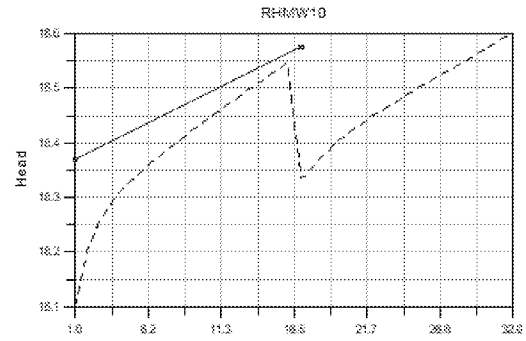
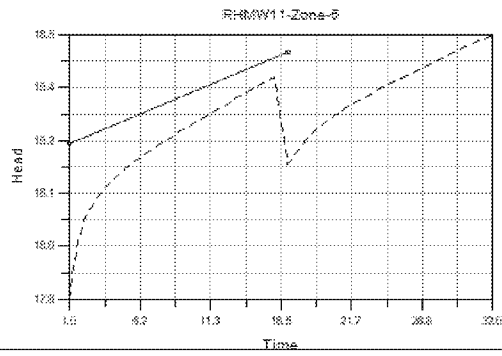
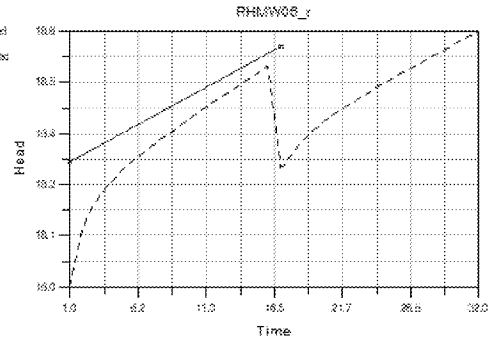
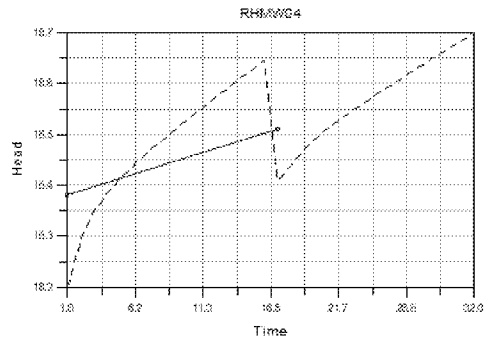
# Well Response Differs in Various Wells



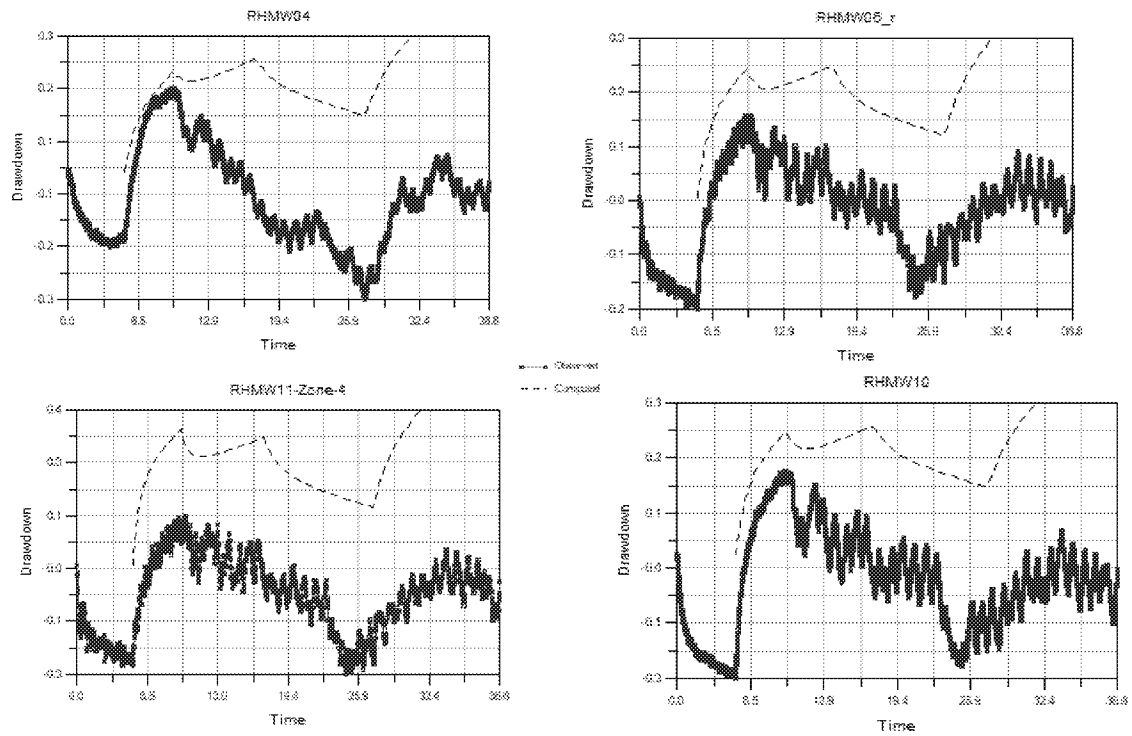
# Non-Uniform Distance Drawdown Behavior



# Example Hydrographs; M51a Base Case



# Example Hydrographs; M51a Verification

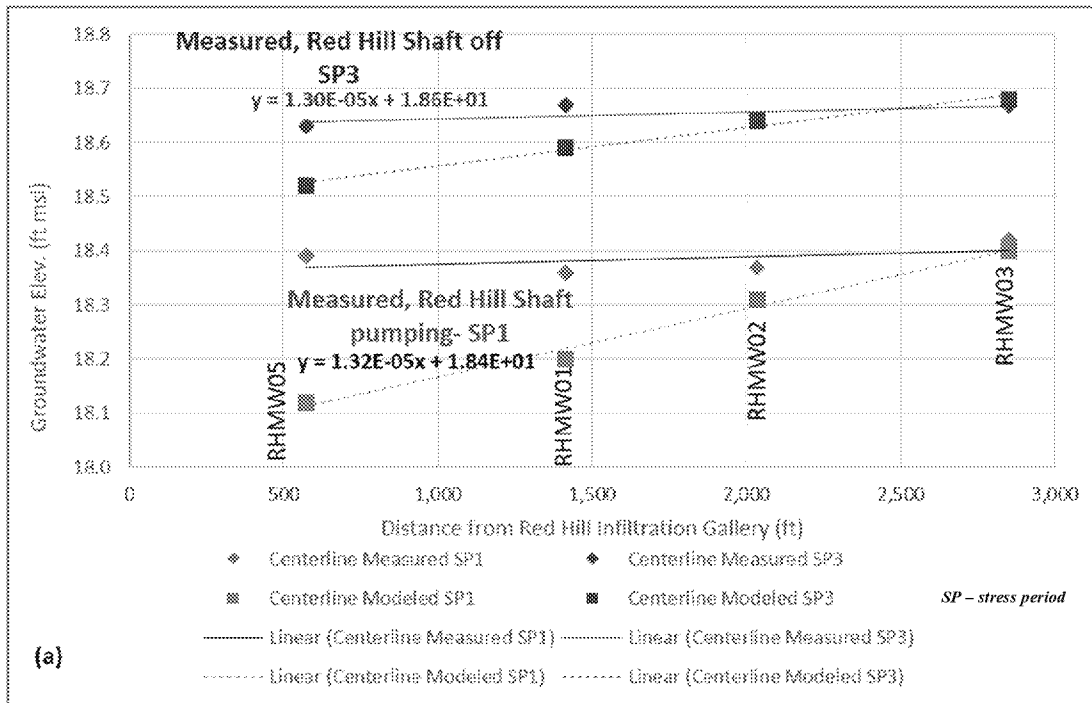


## Prior Key Parameters v. Navy Models

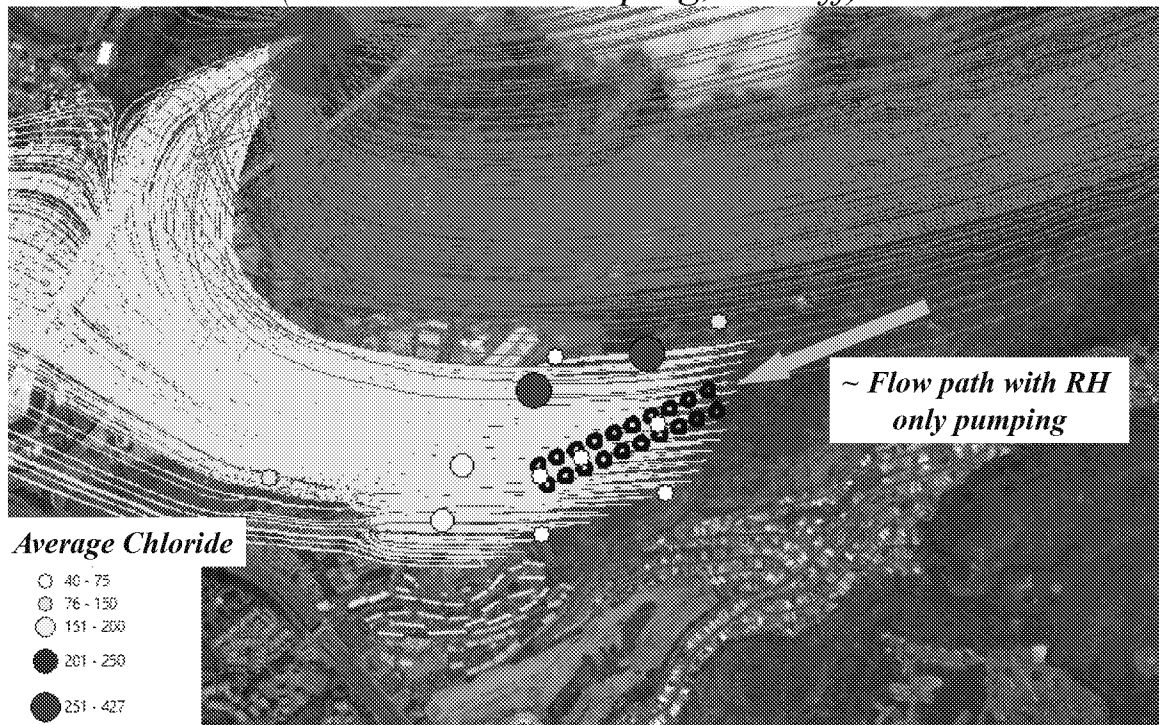
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Hydrostratigraphic Unit	Oki, 2005			Navy GWFM - avgs		
	Kv	Kt	Kl	Kv	Kt	Kl
Volcanic-rock aquifer	7.5	1,500	4,500	65	1,000	2,999
Caprock, upper-limestone unit	25	2,500	2,500	0.01	500	500
Caprock, low-permeability unit						
Above Waianae Volcanics	0.3	0.3	0.3	0.01	1	1
Above Koolau Basalt, west of Waiawa Stream	0.01	0.01	0.01	0.01	1	1
Above Koolau Basalt, east of Waiawa Stream	0.6	0.6	0.6	0.01	1	1
Valley-fill barriers	0.058	0.058	0.058	0.01	1	1

# Modeled Gradients Are Too Large (Red Hill area, no gradient change under pumping)



# Chloride in Groundwater with Model 51A Paths (BWS Halawa Pumping, RH Off)



# Critical GWFM Evaluation Questions

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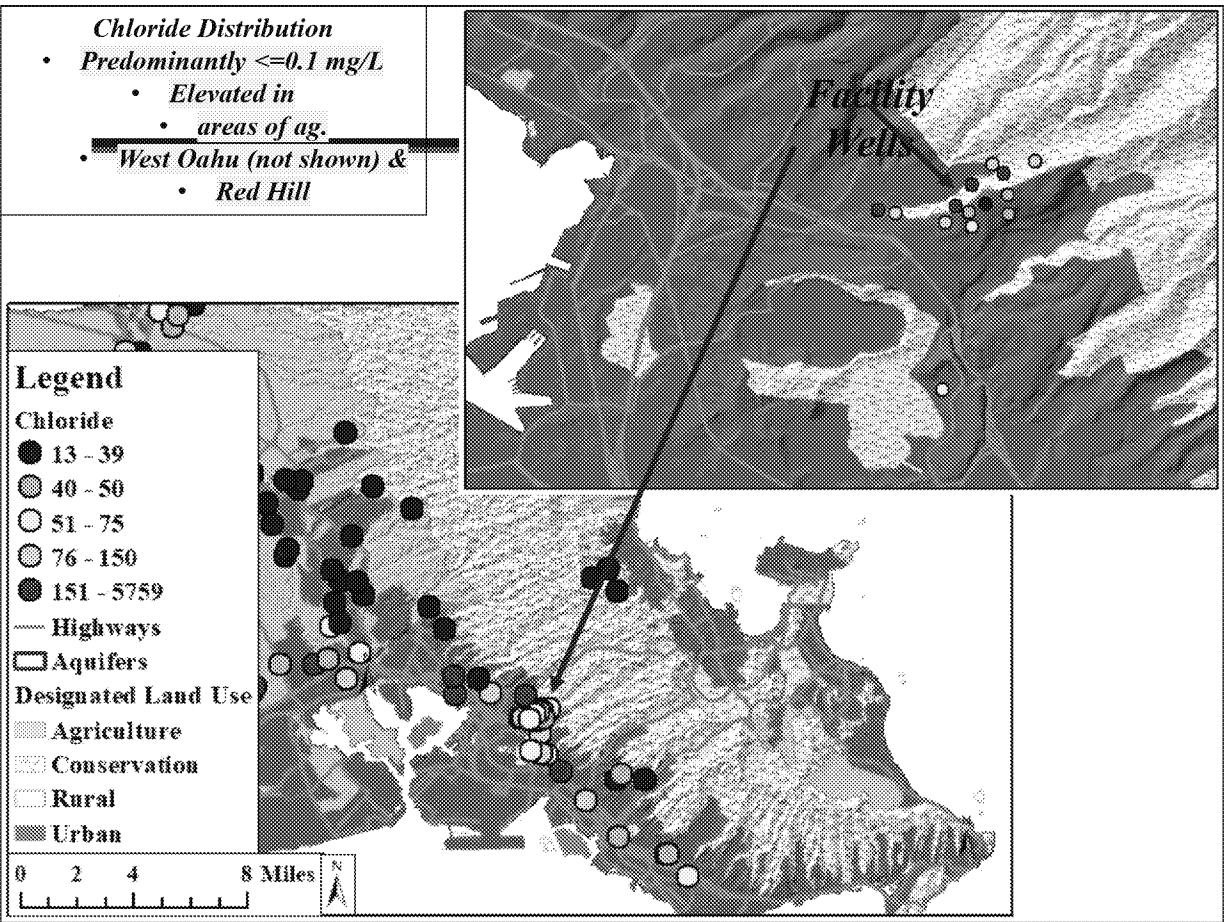
1. What is the model going to be used for?
2. Do we have confidence that the model results are informative for that purpose?

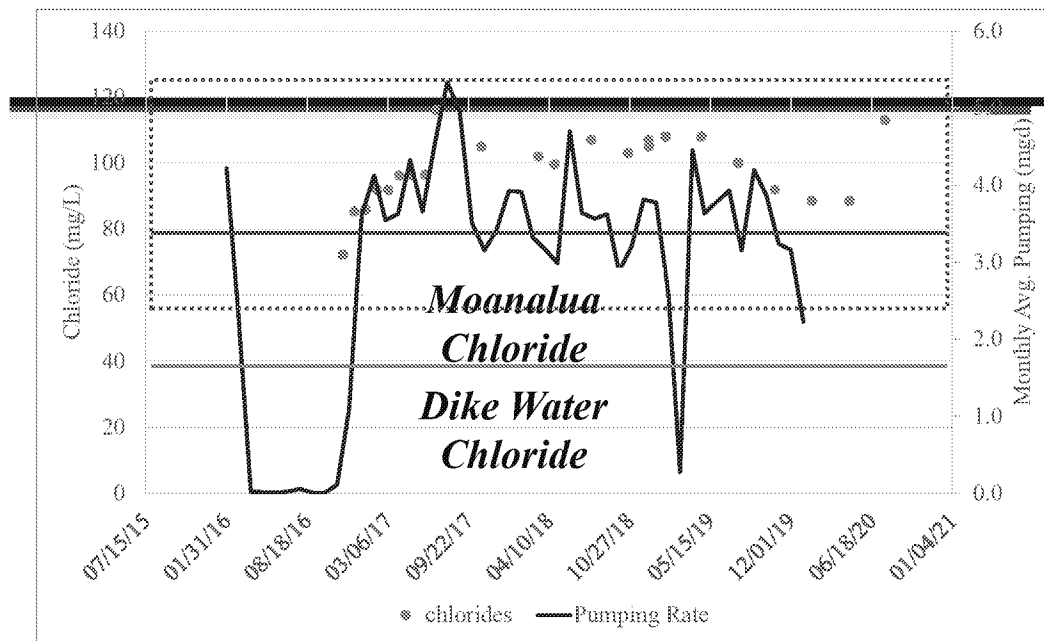
## Comparative Chemistry

Chemical Parameter	Red Hill Shaft	Dike Zone Recharged	Moanalua**	
Chloride	95 73-130	37	82 (57-123)	
$\delta^{18}\text{O}$	-3.2 & -3.0	-3.1	-3.1 (-2.8 to -3.2)	RHS samples 1/9/17 & 4/23/20
$\delta^{15}\text{N}$	5.28	3.99	6.74 (6.15 & 7.33)	Natural dissolve N $\delta^{15}\text{N} \sim 2-3 \text{ ‰}$
$\delta^{34}\text{S}$	16.2	19.4	18.0 17.2 & 18.8	$\sim 18-19 \text{ ‰}$ seems to be a normal range Seawater S $\sim 20 \text{ ‰}$
Fluoride	0.24 & 0.07 & 0.07	0.02	0.03 (0.02-0.05)	RHS Samples 11/14/16 & 1/9/17

\* Kamehameha School A well, upslope on Kalama Ridge

\*\* Moanalua Wells 2&3, Tripler Army Medical Center Supply Well, Honolulu Int'l Country Club Well



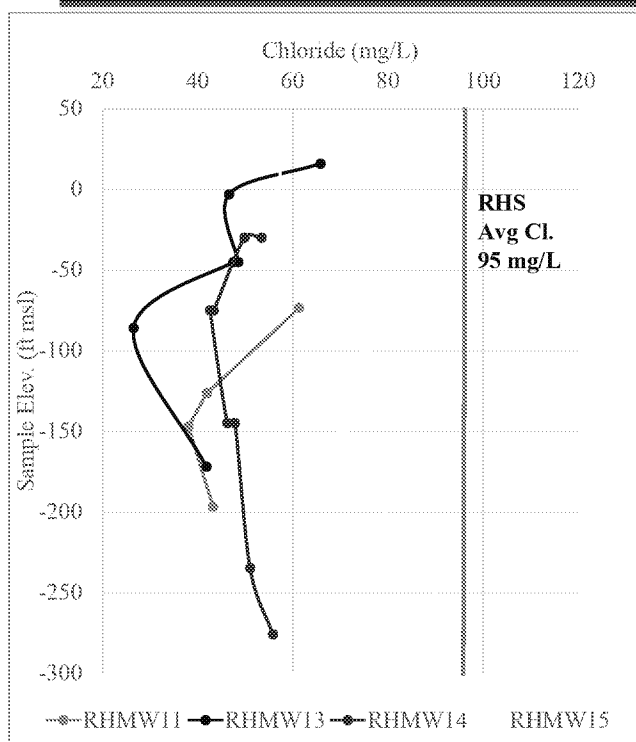


## Incorporating Geochemistry w/o Doing a Transport Model

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- Mixing Equation
  - $C_{\text{mix}} = (C_1 * Q_1 + C_2 * Q_2 + C_3 * Q_3) / (Q_1 + Q_2 + Q_3)$
- Modeled inflow to Red Hill Shaft
  - Deep dike water – 39%; Cl=37 mg/L
  - Moanalua Water – 59%; Cl = 82 mg/L
  - Direct Recharge – 2%; Cl = 25 mg/L
- $C_{\text{mix}}$  Calculated – 63 mg/L
- $C_{\text{mix}}$  measured - ~95 mg/L
- I believe the inflow percentages were for a RHS non-pumping condition
  - If I recall right majority of modeled inflow during pumping was deep dike water.

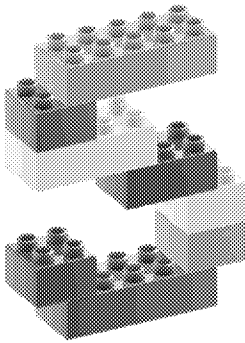
## Westbay Well Chlorides



- Upslope or west of the Red Hill Shaft all  $Cl < RHS\ Cl_{avg}$  of 95 mg/L
- Low Cl in RHMW11, 13, & 14 argue against upflow from HDMW2253 as the source of Cl
- In RHMW15 (near the east end of the RHS infiltration gallery) the chlorides start to approach RHS values between -150 & -260
  - However, water levels indicate a downward gradient

# Model Review Observations

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- GWFM's do not match heads, diminishing reliability
  - In transient verification runs
  - Similar issue as in prior modeling (2007)
- GWFM's use atypical parameters for Hawaii aquifer
  - If retained, in depth justification needed
- GWFM's do not use CSM geologic details – SSPA work
  - Impact of heterogeneity needs further evaluation
- GWFM's do not comport with geochemistry
  - Complex distributions may imply multiple source waters
- GWFM's capture zones not supported by field data at pumping rates similar to those modeled
  - Parameters selected overestimate capture potential
  - Gradient issues & complexity not covered
- As the GWFM's currently stand, they are not reliable
  - For CF&T, risk analyses and mitigation decisions